

TABLE 3.—Wind velocity and direction.

Station.	Mean maximum velocity by direction.								Relative frequency by direction.							
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Eastport, Me.	46	49	38	44	....	38	32	0	121	15	5	5	0	5	7	7
Portland, Me.	30	35	37	39	33	27	31	38	2	9	3	9	5	2	2	125
Boston, Mass.	31	38	34	38	29	30	38	36	4	8	9	2	2	4	119	15
Nantucket.	43	51	54	48	45	53	49	43	4	125	3	2	3	19	2	2
Block Island.	54	50	54	60	....	35	53	56	1	8	6	1	0	2	12	130
Sandy Hook.	50	62	57	60	57	55	63	53	7	3	3	1	11	2	10	126
Atlantic City.	19	35	24	30	25	23	26	32	3	115	5	8	14	6	2	13
Cape May.	30	34	34	45	35	34	33	0	5	5	8	4	1	1	1	114
Cape Henry.	48	49	57	....	48	48	49	125	20	3	0	1	1	0	10	10
Hatteras.	47	44	62	55	50	45	45	47	120	4	1	1	4	8	9	15
Wilmington.	30	37	24	37	35	31	32	38	4	11	5	2	5	121	10	2
Charleston.	38	37	31	35	41	33	38	35	6	121	4	4	9	10	5	5
Savannah.	35	44	31	39	39	44	41	43	4	3	10	6	5	3	13	118
Jacksonville.	44	41	39	37	44	47	52	45	3	6	2	3	6	120	3	6

¹ Indicates prevailing direction.

NOTE.—Data from the following stations is missing: For Cape May, April, July, and August, 1918; January, February, and March, 1919; for Hatteras, October, 1918; for Jacksonville, January, February, March, and April, 1915.

THE ACCURACY OF WIND OBSERVATIONS IN LARGE CITIES.

By G. HELLMANN.

[Abstracted from Bericht über die Tätigkeit des Preussischen Meteorologischen Instituts in den Jahren 1917, 1918, 1919, pp. 24-29.]

The necessity of observing the direction of the wind from wind vanes has led to the placing of vanes on buildings in cities which are but poorly exposed to the wind, and, being influenced by eddies and deflected currents from adjacent buildings, they not only fail to agree in results with those exposed openly but also disagree with other poorly exposed vanes.

The author has investigated this question for five years, 1911-1915, at three stations located in Berlin. The Urban municipal hospital is located near the south limit of Berlin, the Agricultural high school is 4.5 kilometers northwest of Urban, and a third station located in Seestrasse was 3.1 kilometers northwest of the high

school on the northwest limit of Berlin. The relative number of wind directions recorded by the three stations in those years is as follows:

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
Urban.....	100.4	40.0	142.8	77.6	211.4	172.8	193.8	132.2	24.6
High school.....	66.4	103.4	126.0	115.0	118.7	163.2	256.5	124.2	22.2
Seestrasse.....	87.0	112.0	135.2	83.6	158.6	158.0	266.4	84.2	10.6

Most conspicuous in this table are the differences between the three stations with south and with northeast winds. The Urban station recorded about twice as many south winds as the high school, while the Seestrasse station recorded three times as many northeast winds as the Urban station. This is probably due to the situation of these stations with respect to the city. Seestrasse, on the northwest received more northeast winds; Urban, on the south, had a preponderance of south winds.

Of interest, also, are records made between 1775 and 1787 within Berlin, which, then, of course, was much smaller than now. One observer was Beguelin, who observed from the old observatory in Dorotheenstrasse for the Academy of Sciences, and the other was Gronau, the minister of the Parochialkirche, who observed the vane on his church steeple. The two points lay about 1.5 kilometers apart. Their records show very poor agreement as to frequency. The best agreement occurred in the months of May, June, and July when the north wind is prevailing. Throughout the year Gronau had more southwest winds than Beguelin, and, in general, he also recorded more west winds, while Beguelin noted more north, south, and southeast winds.

These records show how unreliable are many of the records of wind direction obtained in cities. The observations of Beguelin and Gronau show also that recording instruments are essential, for their best agreement was in those months when long day light and clear weather aided their observing in morning and evening.—C. L. M.

GROUND TEMPERATURES COMPARED WITH AIR TEMPERATURES IN A SHELTER.

By GEORGE REEDER.

[Weather Bureau, Columbia, Mo., Oct. 19, 1920.]

SYNOPSIS.

A series of observations was made at the United States Weather Bureau Station, University of Missouri, Columbia, during the months of September and October, 1907, to determine how much exposed thermometers on the ground differed from sheltered thermometers 11 feet above the ground. To test the problem further, three beds were made, one of bare soil, one of blue-grass sod, and one of sand. Observations made during the passage of cumulus clouds and upon the effect of a shade area 20 feet distant showed that all the instruments responded to cloud shadows, but that only ground thermometers showed the effect of the building shadow. The latter shadow caused a perceptible movement of air toward the sunlit area. This paper serves to present the collected data from these observations.

RESULTS.

Equipment.—The equipment consisted of maximum, minimum, wet and dry bulb thermometers and a thermograph, in the shelter, and of one minimum and one dry bulb thermometer on each of three beds. The beds consisted of small adjoining plots of bare soil, blue-grass sod, and sand, each 18 inches square. The shelter, which was of the usual Weather Bureau type, stood 11 feet above the ground. The beds lay on the south side of the shelter so that on bright days the shelter shadow was thrown away from the thermometers exposed in the beds.

The thermometers were placed, with the bulbs partly, but not wholly, covered, pointing to the north. For protection from interference and accidents, the three beds were covered with a strong 3-inch mesh wire cage, the four corner wires being driven into the ground. The observations were made with the dry bulb thermometers at 2 p. m. and sunset and each morning with the minimum thermometer.

The accompanying tables and diagram show that during September nights bare soil cools slower than either sod or sand. Generally, it was cooler on the ground during clear nights than in the shelter; during calm, clear, dewy nights bare soil was the warmest, as a rule. In the middle of the day during September, under bright sunshine, bare soil and sand went to higher temperatures than the sod; and the temperature changes with the passage of a cloud also were greater on bare soil and sand than on sod. During cloudy, damp weather ground-surface temperatures were moderate and varied but little. The loss of heat from the bare soil surface was quite marked after September 20.

The warmest period was from September 11 to the 19th, inclusive (see fig. 1). The 16th was the warmest

day. On that date soil, sod, and sand, and the shelter started off with about the same temperature, namely, 67.4°, 66.5°, 66.5°, and 69° F., respectively. By 2 p. m., the highest point had been reached, the thermometer on the bare soil reading 121.5°; on the sod, 109°; on the sand, 126°, and in the shelter, 91° F. At sunset, the readings were, soil 82°, sod, 76°, sand, 85°, and shelter, 84° F.

During October nights, soil seems to be more retentive of its warmth. Sand cools more readily, but differs but little from sod in this respect. In the middle of the day, sand is the warmest and sod the coolest. Sand is the

noticeable movement of air on the ground from the shade out into the sunlit area. This was determined by placing light feathers just inside the shade line. During the hot relatively calm days these feathers moved out into the warm area as far as and beyond the thermometer beds. The instruments were sensitive enough to respond to the cooler shade air.

During passing cumulus clouds the drop in temperature was marked, and this serves to show that every passing cumulus cloud in summer, when it is dry and hot, affords relief to the parched hot earth. It will be noticed that passing clouds not only caused a drop in temperature as recorded by the ground thermometers, but also affected the shelter temperature, although to a smaller extent. The movement of the cooler ground shade air, however, only affected the ground thermometers, the air in the shelter showing no change.

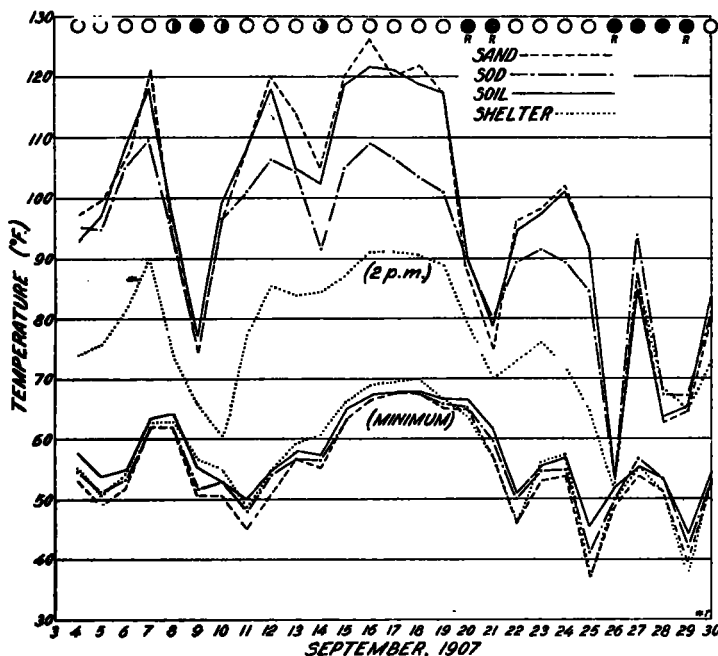


FIG. 1.—2 p. m. (about maximum) and minimum temperatures during September, 1907, in shelter and in various kinds of earth.

warmest under nearly all conditions, even when covered by leaves. After the first week, the sod began to turn a grayish brown.

The cooling effect of radiation from the thermometer shelter was indicated, as usual,¹ by lower temperatures in the shelter than on ground on clear nights. The first autumn frost seemed to cause more damage several, say 10 to 15, feet above ground than immediately on the ground; tops of small trees, and the tassels and top blades of corn, appeared to be damaged first, evidently because radiation from lower, sheltered portions was limited.

During the middle of the day in October, the air in contact with sod was consistently cooler than the air in the shelter 11 feet above ground; and on one day, the 26th (a rainy day), it was cooler in the shelter than on the ground, including soil, sod, and sand.

Effects of deep shade and passing clouds.—A few observations were made to determine what effect near-by shade and the shadows cast by passing cumulus clouds had on the ground-surface thermometers during a warm September spell.

A building south of my experimental plot cast a deep shade within about 20 feet of the thermometers on the ground. During the hot spell of September, there was a

TABLE 1.—Temperatures on various types of days.

	Rain.			Clear.					
	Minimum.	Maximum (2 p. m.).	Sunset.	Wet ground.			Dry ground.		
				Minimum.	Maximum (2 p. m.).	Sunset.	Minimum.	Maximum (2 p. m.).	Sunset.
Soil.....	° F. 53.1	° F. 63.9	° F. 55.0	° F. 50.9	° F. 94.5	° F. 64.0	° F. 66.5	° F. 117.5	° F. 83.9
Sod.....	53.6	67.9	54.0	50.0	89.5	61.0	66.0	101.0	77.9
Sand.....	51.5	67.9	54.5	46.0	96.0	65.9	65.2	117.0	85.0
Shelter.....	51.3	68.1	53.1	46.0	73.0	66.0	66.6	89.0	83.8

TABLE 2.—Temperatures at time of first killing frost.

	Oct. 11, sunset.	Oct. 12, minimum.	Fall.	Oct. 12, sunset.	Oct. 13, minimum.	Fall.
Soil.....	° F. 47.2	° F. 35.5	° F. 11.7	° F. 44.9	° F. 31.6	° F. 13.3
Sod.....	44.1	31.6	12.5	41.0	29.5	11.5
Sand.....	49.0	30.7	18.3	46.0	26.3	19.7
Shelter.....	52.8	32.0	20.8	47.5	25.5	22.0

TABLE 3.—Monthly averages of temperatures.

	September.			October.		
	Minimum.	Maximum (2 p. m.).	Sunset.	Minimum.	Maximum (2 p. m.).	Sunset.
Soil.....	° F. 57.5	° F. 97.7	° F. 69.7	° F. 45.1	° F. 68.9	° F. 52.5
Sod.....	56.2	92.1	65.7	43.0	66.2	51.3
Sand.....	54.6	97.6	70.4	42.8	71.2	54.3
Shelter.....	53.6	77.0	71.4	44.9	64.1	58.3

TABLE 4.—Temperatures in bright sunshine, and when the sun is obscured by cumulus clouds.

Sept. 15.	Bright sunshine immediately preceding cloud.	Sun covered 4 ^m 6 ^s ; fell to—	Amount of fall.	4 ^m 6 ^s of bright sunshine immediately following cloud.	Amount of rise.
Soil.....	° F. 119.0	° F. 111.0	° F. 8.0	° F. 116.2	° F. 5.2
Sod.....	106.0	100.0	6.0	102.0	2.0
Sand.....	119.0	110.0	9.0	113.8	3.8
Shelter.....	87.0	86.0	1.0	86.2	0.2

Wind velocity, m. p. h., 2; direction, south.

The following comparative readings were made under similar conditions, except the sun was covered 5^m 30^s.

Sept. 18.	Bright sunshine immediately preceding cloud.	Sun covered 5 ^m 30 ^s fell to —.	Amount of fall.	5 ^m 30 ^s of bright sunshine immediately following cloud.	Amount of rise.
	°F.	°F.	°F.	°F.	°F.
Soil.....	122.2	111.0	11.2	119.0	8.0
Sod.....	108.0	99.5	8.5	103.7	4.2
Sand.....	122.0	113.0	9.0	121.8	8.8
Shelter.....	90.0	88.2	1.8	90.3	2.1

Wind velocity, m. p. h., 2; direction, south.

Comparative readings in bright sunshine every 15 minutes, Sept. 16

	1:00 p. m.	1:15 p. m.	1:30 p. m.	1:45 p. m.	2:00 p. m.	2:15 p. m.	Average variability.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Soil.....	118.0	119.5	121.5	121.5	121.5	119.5	1.9
Sod.....	109.0	108.5	109.0	107.5	109.0	104.5	1.4
Sand.....	121.5	121.5	125.0	125.5	126.0	122.0	1.5
Shelter.....	89.0	89.0	89.5	91.0	91.0	91.0	.....

Wind velocity, m. p. h., 2; direction, southwest.

Comparative readings in bright sunshine every 5 minutes, Sept. 17 and 18.

Sept. 17.	2:15 p. m.	2:20 p. m.	2:25 p. m.	2:30 p. m.	2:35 p. m.	2:40 p. m.	Average variability.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Soil.....	119.5	119.0	119.5	120.8	107.0	104.2	3.1
Sod.....	104.5	104.2	105.0	106.0	104.0	101.0	1.2
Sand.....	122.0	121.0	121.9	124.8	121.0	118.0	1.9
Shelter.....	90.4	90.4	91.0	91.6	91.6	90.9	0.2

Wind velocity, m. p. h., 3; direction, southwest.

Sept. 18.	1:30 p. m.	1:35 p. m.	1:40 p. m.	1:45 p. m.	1:50 p. m.	1:55 p. m.	2:00 p. m.	Average variability.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Soil.....	118.0	114.0	116.6	119.7	119.0	117.0	121.0	2.2
Sod.....	105.0	102.0	103.9	106.0	106.0	104.0	106.5	1.6
Sand.....	118.0	113.3	117.0	119.0	118.8	116.2	120.0	2.4
Shelter.....	90.0	89.0	89.0	90.0	90.9	90.9	91.0	.....

Wind velocity, 2; direction, south.

¹ Movement of cooler shade temperature to thermometer beds.
² Passing cumulus cloud.

THE COOLING OF THE SOIL AT NIGHT, WITH SPECIAL REFERENCE TO LATE SPRING FROSTS.

By T. BEDFORD FRANKLIN.

[Abstracted from *Proceedings of the Royal Society of Edinburgh*, session 1919-20, Vol. XL, Pt. I, pp. 10-22.]

In a previous paper¹ Dr. Franklin came to the conclusion that the temperature of the surface of open cultivated soil fell rapidly at the beginning of a calm, clear night, until it was such a number of degrees below the temperature at the 4-inch depth as to make the upward conduction from that depth to the surface balance the radiation. After this stage was reached the surface and 4-inch temperatures fell at the same rate.

If, therefore, the temperatures of the surface and 4-inch depth and the conductivity of the layer of soil between the 4-inch depth and the surface were known from readings of electrical resistance thermometers, and the rate

of radiation was calculated from the value of the relative humidity, he suggested that it might be possible to forecast the minimum soil temperature for a calm, clear night as early as the previous afternoon.

In this second paper Dr. Franklin gives a formula for forecasting the minimum surface-soil temperature and compares this minimum with the air temperature immediately above.

He found that the conductivity of this surface layer of soil varied so greatly with different degrees of wetness that an average value could not be used. He therefore has adopted, instead, the ratio of the range of temperature at the 4-inch depth and at the surface, which he expresses by $\frac{R_1}{R_0}$.

The quantities required for the forecast equation are:

(1) The value of $\frac{R_1}{R_0}$ from minimum to maximum, which can be obtained by about 5 or 6 o'clock p. m.

(2) The lag on the day in question; this may be observed by about 5 or 6 p. m., or may be found from the values of $\frac{R_1}{R_0}$.

(3) The estimated relative humidity of the coming night.

(4) The number of degrees (θ) which the surface can fall below the 4-inch temperature before the upward conduction balances the radiation; this depends on $\frac{R_1}{R_0}$ and the relative humidity.

(5) The probable difference between the air minimum over open-soil and the surface-soil minimum.

1. Observations show that the ratio of $\frac{R_1}{R_0}$ averages 0.42 immediately after a rain and 0.23 in dry soil. Intermediate results were found with varying amounts of soil moisture. These figures are for the particular soil and location where the records were taken. Dr. Franklin believes that only slight variations would be found at different places in the same type of soil. While he has not fully investigated the ratio in different soil types, he is of the opinion that the ratio will vary between 0.44 and 0.28 for loam, 0.60 and 0.41 for sand, and 0.41 and 0.35 for clay under similar weather conditions.

2. The lag between the 4-inch and the surface temperatures varies from 3½ hours when $\frac{R_1}{R_0}$ equaled 0.44 to 5½ hours when the ratio was 0.20 and was fairly proportioned between these ratios.

3. The connection between $\frac{R_1}{R_0}$, the relative humidity, and the number of degrees centigrade (θ) which the surface can fall below the temperature of the 4-inch depth before the upward conduction balances the radiation is shown in the following table:

Values of θ in °C.

Relative humidity.	Values of $\frac{R_1}{R_0}$							
	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.44
90 per cent.....	8.0	7.5	7.0	6.5	6.0	5.5	5.0	4.6
80 per cent.....	8.7	8.1	7.6	7.0	6.5	6.0	5.5	5.0
70 per cent.....	9.5	8.9	8.3	7.7	7.1	6.6	6.1	5.5
60 per cent.....	10.2	9.6	9.0	8.4	7.8	7.2	6.6	6.1

¹ See review in MONTHLY WEATHER REVIEW, Dec., 1919, 47: 849.